# Integration of Spectrum Database and Sensing Results for Hybrid Spectrum Access Systems

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# Outline

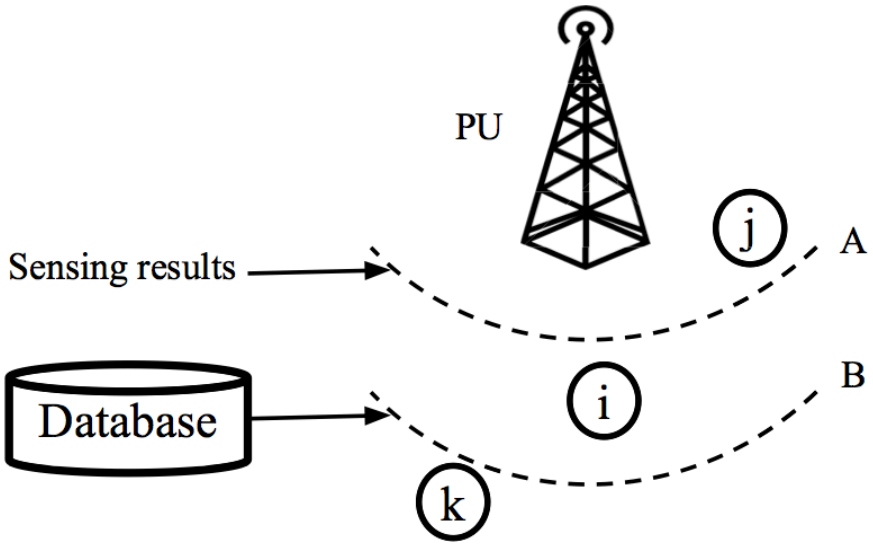
- *Motivation*
- Overview
- Integration framework
  - Depict spectrum map
  - Integration process
- Performance evaluation
- Conclusion

# Motivation

- Cognitive radio networks
  - Spectrum sharing between primary user and Secondary user
- Spectrum sensing *Vs* Spectrum database
  - Aggressive *Vs* Conservative
- What about a combination…

# Motivation

- Integration is not that easy:
  - Coverage issue
  - Weighted spectrum information



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# Overview

- We propose our integration framework, for the hybrid spectrum access systems of the database-driven and sensing-based models.
- We make use of the spacial-based statistical methods to predict the sensing information for locations that have no sensing results reported.
- We propose a scheme to find a balanced combination of the database information and sensing results, which evaluate the current weight assignments and make iterative adjustments.

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# Integration Framework

- Ensure coverage
  - Depict spectrum map from sensing results
- Combine sensing results with database information
  - Formulate as partially observable Markov decision process

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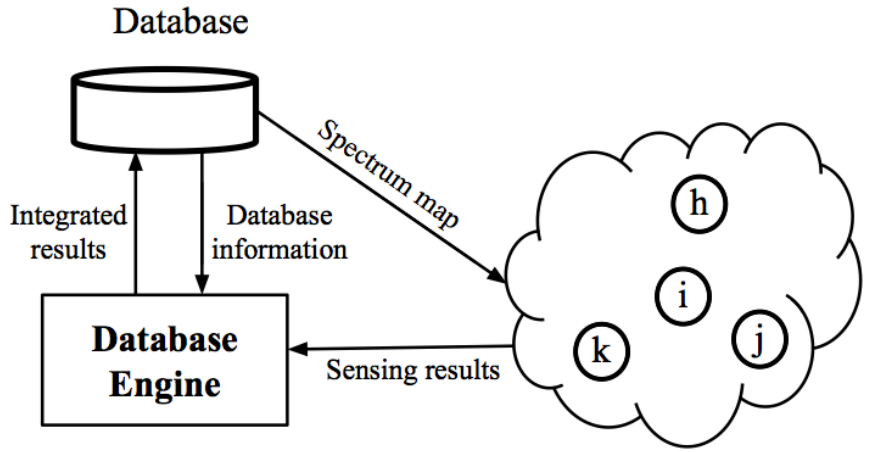
# Depict Spectrum Map

- Collect spectrum sensing results
- Make estimation for unknown area
- Process collected and estimated results

# Depict Spectrum Map

- The key point is: *sensing results are not directly used for spectrum access, but for depicting spectrum map.*



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# Integration Process

- How to integrate: Iterative way.
  - Given the information from two resources, adjust the weights for each part..

- Observe → Adjust → Observe …

# Integration Process

- Formed as partially observable Markov decision process
  - *State*: balanced, conservative, aggressive
  - *Action*: produce state conclusion, plus taking measurement without state change
  - *State transition probability*: State evolvement
  - *Reward*: correct/incorrect state, measurement cost.
  - *Observation*: feedback from secondary users
  - *Belief*: Based on current observation and last action.

# Integration Process

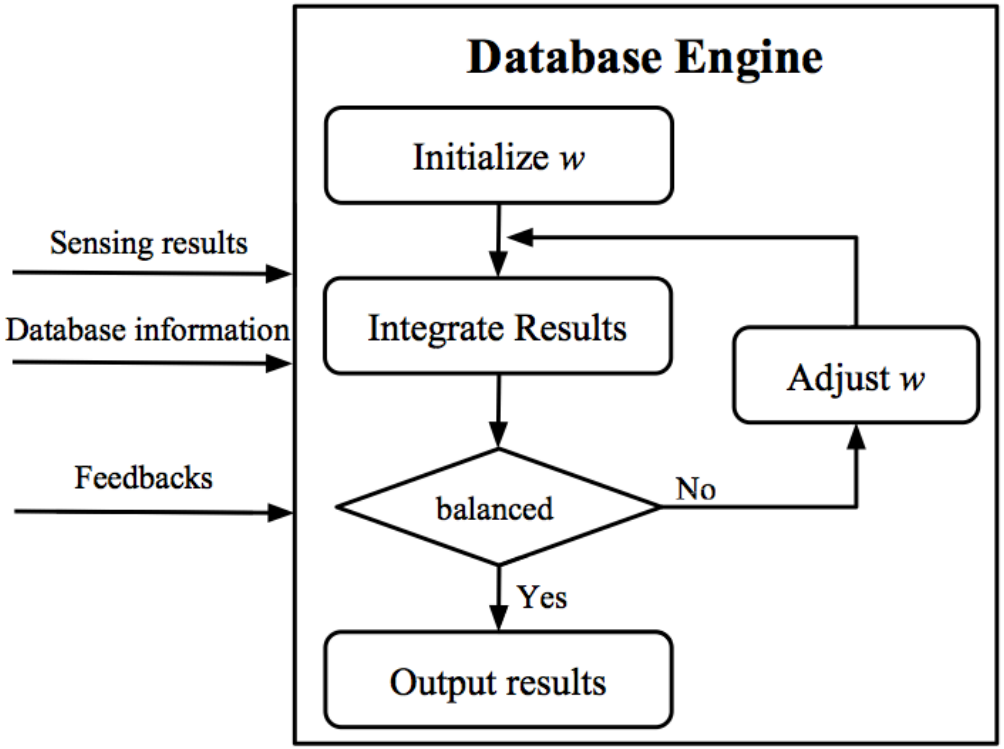
- Dynamic integration policy
  - Stepwise
  - Case study: Maximum allowed interference
  - Acceptable range
  - Triggered when balanced status is broken

# Integration Process

1. $status = conservative$; // $status$ has three values.
2. $unchanged = true$, $step = w/2$;
3. **while** $status \neq balanced$ **do**
4. **if** $unchanged = false$ **then**
5. $step = step/2$;
6. **if** $status = conservative$ **then**
7. $w = w - step$;
8. **else**
9. $w = w + step$;
10. $\tilde{I} = w \times I_d + (1 - w) \times I_s$;
11. Update $status$ based on the POMDP output;
12. **if** $status$'s value is changed **then**
13. $unchanged = false$;
14. **else**
15. $unchanged = true$;
16. **return** $\tilde{I}$.

# Integration Process

- Main flow graph:



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# Performance Evaluation

- Primary users:
  - Randomly distributed
  - Different transmission range and channel
- Secondary users:
  - Randomly distributed
  - Simulated accurate sensing results
- Database engine:
  - Primary users' transmission range
  - Maximum allowable interference

# Performance Evaluation

- Settings:

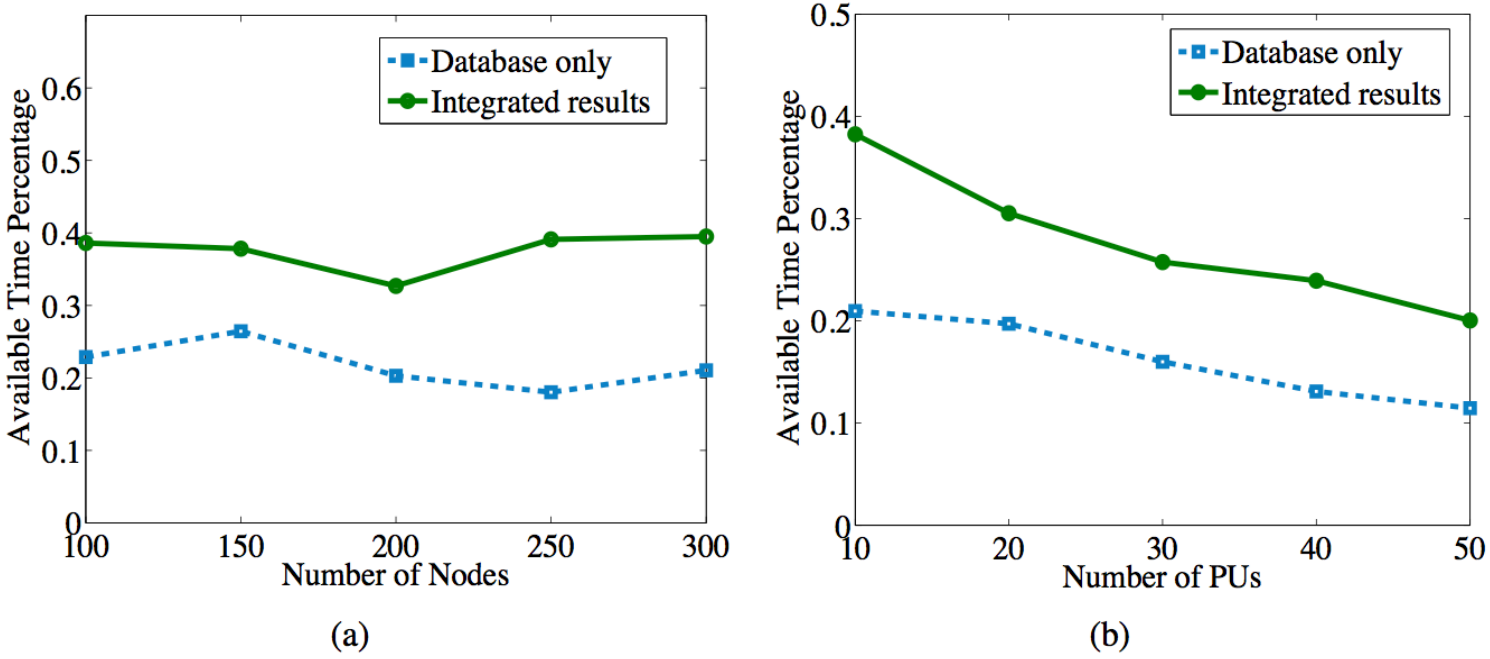
| | |
|---|---|
| Number of nodes | $[100, 300]$ |
| Number of channels | $[2, 10]$ |
| Average sensing time | $0.5s$ |
| TX power | 23 dBm |
| Noise power | $-98$ dBm |
| SINR threshold | 10 dB |
| Number of PUs | $[10, 50]$ |
| PU active duration | $[20, 30]s$ |
| PU active period | $[10, 20]s$ |
| Operation range of each PU | $[300, 500]$ |

# Performance Evaluation

- Performance metrics
  - Available time percentage
    - The percentage of the available time durations over the total time.
  - Ratio of transmission time over sensing time
    - A larger value of the ratio indicates that the transmission is less frequently interrupted by primary users

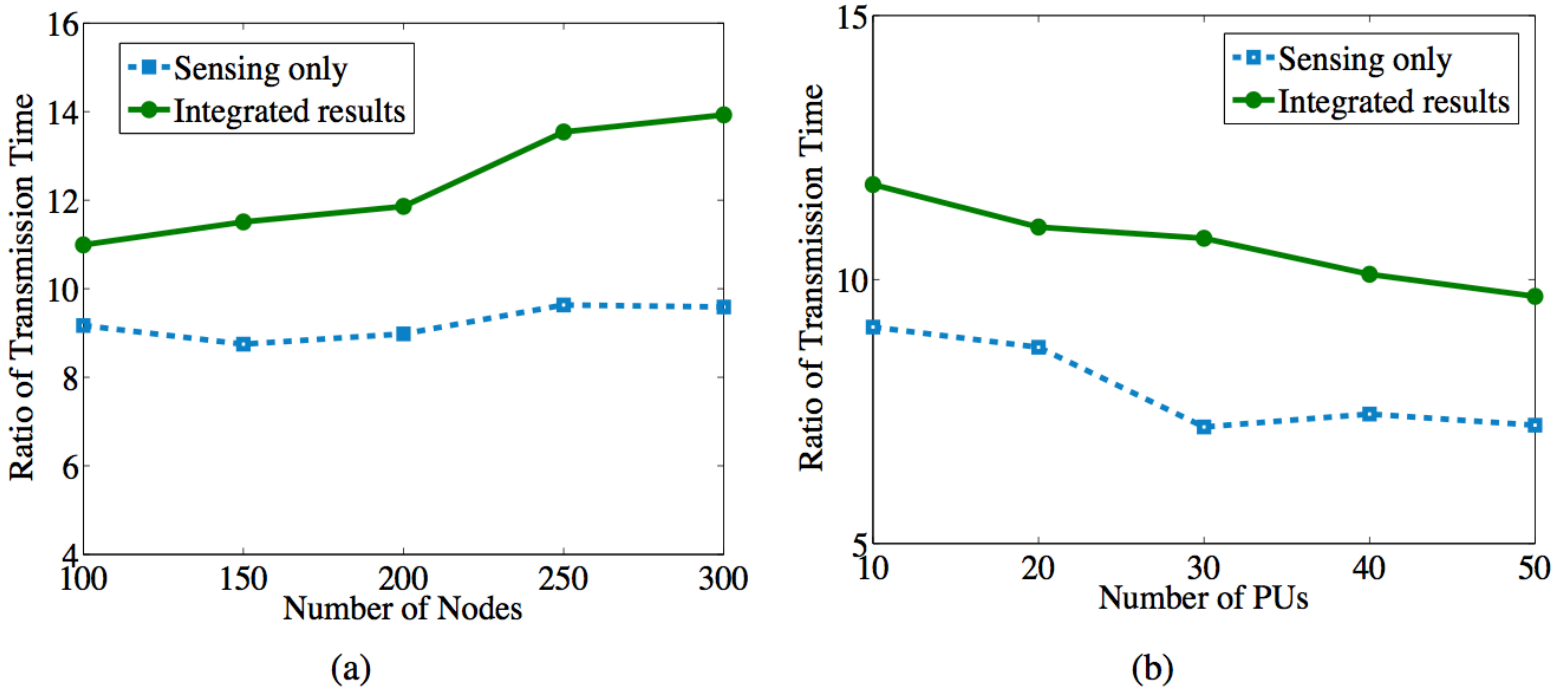
# Performance Evaluation

- Available time percentage:



# Performance Evaluation

- Ratio of transmission time over sensing time



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# Conclusion

- Integration framework
- Coverage issue
- Dynamic integration policy

# Thank you!